P-48: Pixel-based Optical Feedback to Correct Ageing and Non-uniformities in Large-area Displays

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Abstract

Current AM addressing with peripheral drivers is not suited to tackle the problem of individual pixel deterioration for example due to aging or non-uniformity of different pixels in the display (a problem proportional to the size of the display). Therefore we pro-pose to integrate the driver electronics underneath each pixel, deviating from current display layouts. Thus it be-comes possible to implementing optical feedback for each pixel. A prototype of a driver with an optical feed-back loop was designed in a high voltage CMOS technology with integrated optical detectors.

1. Introduction

Self-emissive displays find it hard to combine large display sizes with uniformity of the pixels throughout the entire display. Improving production methods might ameliorate the display characteristics, but as display size increases, large area displays (LAD's) suffer from poorer uniformity and linearity simply due to large scale. Also, because of ageing of the display, the emissive characteristics of individual pixels change and thus nonuniformity increases with time.

We propose to tackle this problem by providing each pixel with optical feedback which controls the amount of light emitted by the pixel, keeping it constant regardless the characteristics of the individual pixel. As current active matrix addressing doesn't allow the parallel monitoring of all pixels, we propose a different design of the display by providing each pixel with a separate and individual driver chip. As the driver chip can contain a certain amount of intelligence, there is no need for an addressing matrix separately selecting each pixel. In addition each pixel gets his own driver and thus works independently from other pixels, so the display can consist out of separate pixel elements. This way, critical dimensions could be reduced to pixel level drastically improving production yield. Moreover, this approach allows easy repairs (each pixel is replaceable) and possibility to cut the display to desired size or even shape! Each pixel is provided with a microchip that requires 8 bit data to generate (and correct) a certain grayscale. This data stream can be individually addressed (in which case each chip must have a unique ID) or shifted through from chip to chip. To reduce the data frequency the display might be build as a combination of tiles which are driven in parallel.

2. Optical Feedback

The basic idea for the optical feedback consists of capacitor which is being charged to a certain voltage and an optical CMOS detector integrated on chip which discharges the capacitor with a detected photocurrent. The voltage over the capacitor is monitored by a comparator which controls the output stage towards the pixel cathode. The CMOS optical detector will generate a photocurrent proportional to the emissive characteristics of the pixel. As the capacitor is charged with a fixed voltage (proportional to the desired grayscale), the charge on the capacitor corresponds with a certain amount of emitted optical energy. A stronger emitting pixel will therefore discharge the capacitor faster and will be switched of faster then a less emitting pixel. At the end of the frame, each pixel, regardless of its emissive characteristics, will have emitted the same amount of optical energy. Figure 1 illustrates this principle.

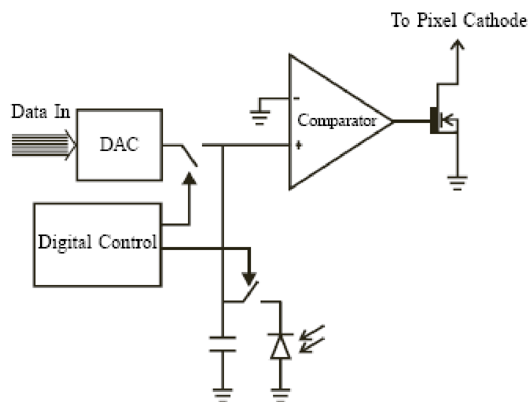

Figure 1: Optical feedback loop

The optical feedback can be implemented in different ways: a real-time feedback or a calibration feedback.

2.1 Real-time feedback

Real-time feedback means the optical detector works constantly during playback and every frame the capacitor is discharged with the photocurrent. We have made a prototype with two different real-time feedback loops. In the first possibility the capacitor is charged with a voltage, generated by a DAC, proportional to the desired grayscale. The capacitor is then discharged by the photocurrent during the entire frame length (60 Hz - 16.6 ms).

The second option is to divide the 16.6 ms frame into 256 basic frames, each representing 1 level of grayscale. In this case, the capacitor is discharged during each entity and the grayscale is generated by the number of basic frames, which can be done digitally by a counter. The first option requires a lower bandwidth but needs a DAC to generate the analog voltage to which the capacitor must be charged, which deteriorates the linearity of the loop. The second option however, has no need for a DAC because the capacitor is always charged to the same voltage. However, the bandwidth must be much higher. Furthermore, a stronger photocurrent must be available to discharge the capacitor in a smaller time. The capacitor will be chosen as small as possible but a too small capacitor makes the

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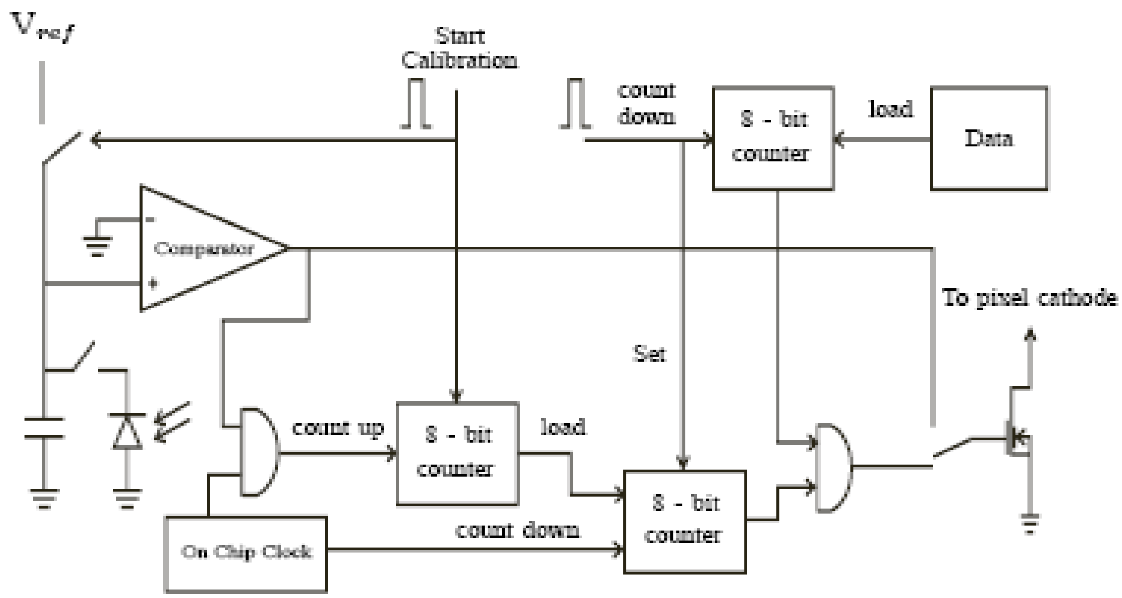

Figure 2: Optical feedback loop – calibration cycle

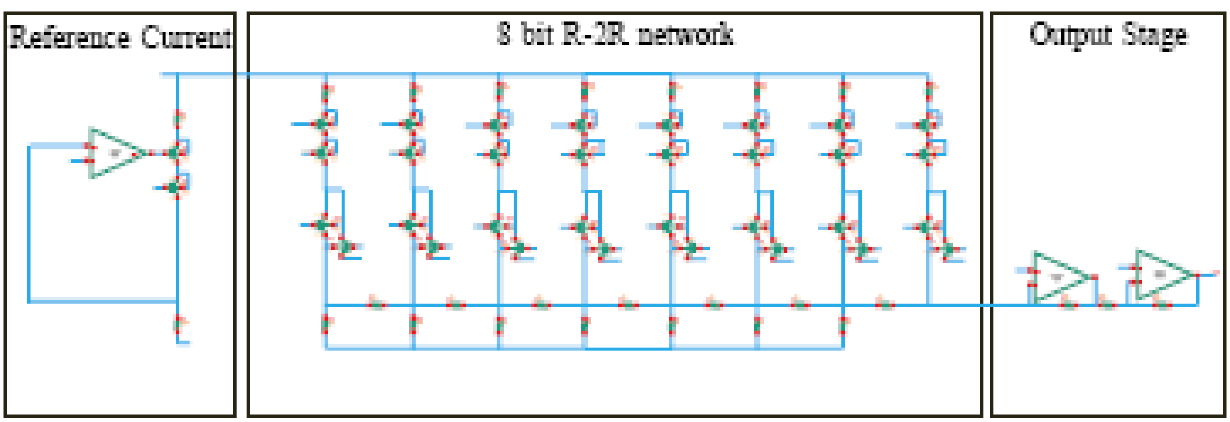

Figure 3: DAC Voltage Generator

loop too vulnerable to leak currents and charge injections from the switches.

2.2 Calibrated feedback

Besides real-time feedback during playback, another option is being considered. Only during switch-on of the display a feedback calibration cycle is carried out. The time it takes the pixel to discharge the capacitor during the emission of a single grayscale, is measured digitally (e.g. via a counter) and can be used to drive the pixel from then on. Whereas the real-time feedback loops require one photo detector for each pixel, they can only drive mono-color pixels and a separate driver chips is needed for each color. The method with pre-calibration allows a single photo detector to be used subsequently for different colors. Thus, a three color pixel element can be driven with a single driver chip.

3. Driver Chip

We designed a prototype of a pixel driver chip for driving a CNT based FED in the high voltage I2T 100 technology. The 8 bit DAC used to charge the capacitor, is shown in figure 3: a pmos

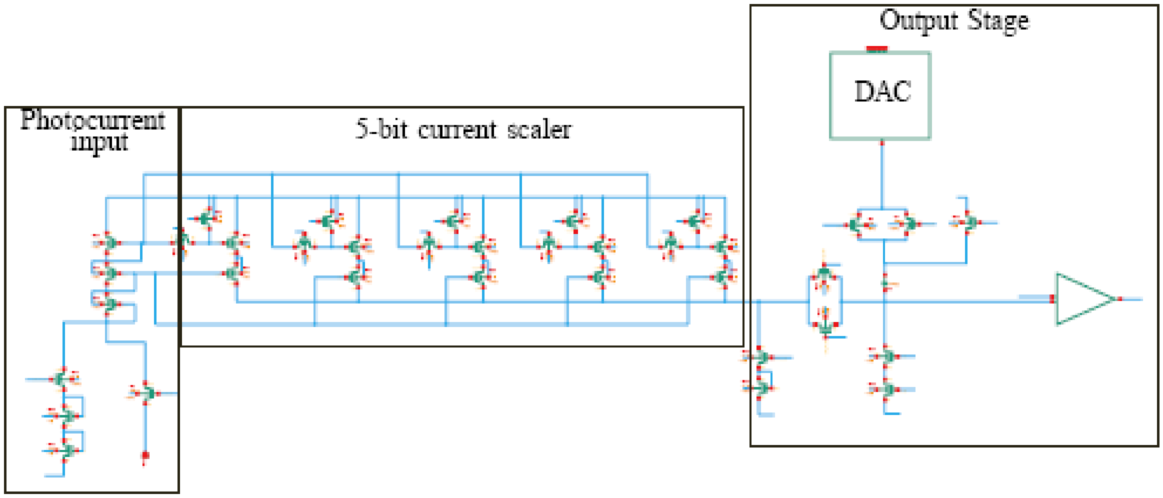

Figure 4: Realtime feedback loop

VT-reference voltage (not shown on figure), combined with a very low bandwidth opamp, is used to create a stable reference current. From this current 8 current sources are derived. To reduce the silicon area, a R/2R with small resistors was chosen to scale the currents to $I_{ref} \cdot 2^{i}$, in stead of scaling the currents by transistor size. To ensure equality of the currents injected in the R/2R network, an additionally cascode and emitter feedback are used. The opamp output stage transfers the established current to a corresponding voltage. The opamps were designed with high bandwidth and can generate large current, so the capacitor can be charged in very short time.

Figure 4 shows the schematic of a total real-time feedback loop. The on chip photodiodes are designed to a 1 nA current, so the input stage and current mirrors consist of quite large transistors which have bad dynamic response when the photo detector starts generating current. Therefore an extra path is included to keep the mirrors active even when no light is emitted. This way, the dynamic characteristics of the loop are drastically improved.

As the photo detectors might suffer from low reproducibility of characteristics, a 5-bit current scaler is included in the loop. First the photo detector will be illuminated with a known light source

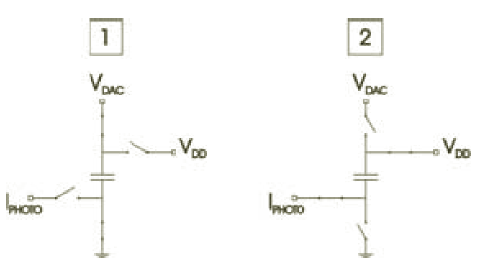

Figure 5: switching of capacitor

to measure the response characteristic. With this information, the feedback loop can be calibrated and the 5-bit current scaler can be set. The output stage consists of the capacitor, the DAC and the necessary switches. First the capacitor is charged to V_{DAC}. Then the switches connect the capacitor to V_{dd} so a positive I_{photo} can discharge the capacitor. This way there is no need for an extra current mirror. Special care had to be taken that the charge from the different switches does not change the total charge on the capacitor. A comparator (followed by a digital port to increase the gain) detects the end of the discharging cycle. This signal is used in a digital circuit to drive the different switches and the output stage to the pixel cathode.

4. Conclusions

By means of the proposed techniques uniformity and lifetime of emissive displays can be improved. The technique is especially suited for large area displays as the new way of addressing allows easier production processes and smaller critical dimensions. Furthermore, as photosensitive devices were made in an existing high voltage technology[4], the technique is also applicable to those displays that require higher driving voltages. A driver chip implementing the optical feedback principle has been designed and is currently being tested.

5. References

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